

FROM UNINTEGRATED GLUON DISTRIBUTIONS TO PARTICLE PRODUCTION IN HADRONIC COLLISIONS AT HIGH ENERGIES

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February 1, 2008

Abstract

The inclusive distributions of gluons and pions for high-energy NN collisions are calculated. The results for several unintegrated gluon distributions (UGD's) from the literature are compared. We find huge differences in both rapidity and p_t of gluons and π 's in NN collisions for different models of UGD's. The Karzeev-Levin UGD gives good description of momentum distribution of charged hadrons at midrapidities. We find that the gluonic mechanism discussed does not describe the inclusive spectra of charged particles in the fragmentation region.

1 Introduction

The recent results from RHIC (see e.g. [1]) have attracted renewed interest in better understanding the dynamics of particle production, not only in nuclear collisions. Quite different approaches have been used to describe the particle spectra from the nuclear collisions [2]. The model in Ref.[3] with an educated guess for UGD describes surprisingly well the whole charged particle rapidity distribution by means of gluonic mechanisms only. Such a gluonic mechanism would lead to the identical production of positively and negatively charged hadrons. The recent results of the BRAHMS experiment [4] put into question the successful description of Ref.[3]. In the light of this experiment, it becomes obvious that the large rapidity regions have more complicated flavour structure.

I discuss the relation between UGD's in hadrons and the inclusive momentum distribution of particles produced in hadronic collisions. The results obtained with different UGD's [3, 5, 7, 8, 9] are shown and compared.

2 Inclusive gluon production

At sufficiently high energy the cross section for inclusive gluon production in $h_1 + h_2 \rightarrow g$ can be written in terms of the UGD's "in" both colliding hadrons [10]

$$\frac{d\sigma}{dy d^2p_t} = \frac{16N_c}{N_c^2 - 1} \frac{1}{p_t^2} \int \alpha_s(\Omega^2) \mathcal{F}_1(x_1, \kappa_1^2) \mathcal{F}_2(x_2, \kappa_2^2) \delta(\vec{\kappa}_1 + \vec{\kappa}_2 - \vec{p}_t) d^2\kappa_1 d^2\kappa_2. \quad (1)$$

Above \mathcal{F}_1 and \mathcal{F}_2 are UGD's in hadron h_1 and h_2 , respectively. The longitudinal momentum fractions are fixed by kinematics: $x_{1/2} = \frac{p_t}{\sqrt{s}} \cdot \exp(\pm y)$. The argument of the running coupling constant is taken as $\Omega^2 = \max(\kappa_1^2, \kappa_2^2, p_t^2)$.

Here I shall not discuss the distributions of "produced" gluons, which can be found in [11]. Instead I shall discuss what are typical values of x_1 and x_2 in the jet (particle) production. Average value $\langle x_1 \rangle$ and $\langle x_2 \rangle$, shown in Fig.1, only weakly depend on the model of UGD. For $y \sim 0$ at the RHIC energy $W = 200$ GeV one tests UGD's at $x_g = 10^{-3} - 10^{-2}$. When $|y|$ grows one tests more and more asymmetric (in x_1 and x_2) configurations. For large $|y|$ either x_1 is extremely small ($x_1 < 10^{-4}$) and $x_2 \rightarrow 1$ or $x_1 \rightarrow 1$ and x_2 is extremely small ($x_2 < 10^{-4}$). These are regions of gluon momentum fraction where the UGD's is rather poorly known. The approximation used in obtaining UGD's are valid certainly only for $x < 0.1$. In order to extrapolate the gluon distribution to $x_g \rightarrow 1$ I multiply the gluon distributions from the previous section by a factor $(1 - x_g)^n$, where $n = 5-7$.

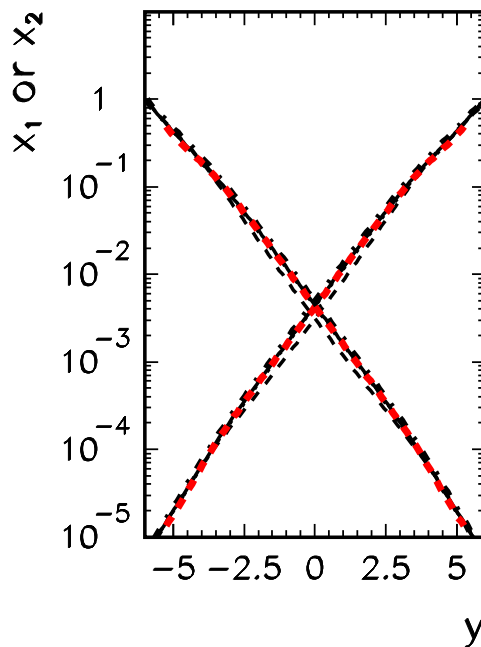


Figure 1: $\langle x_1 \rangle$ and $\langle x_2 \rangle$ for $p_t > 0.5$ GeV and at $W = 200$ GeV.

3 From gluon to particle distributions

In Ref.[3] it was assumed, based on the concept of local parton-hadron duality, that the rapidity distribution of particles is identical to the rapidity distribution of gluons. In the present approach I follow a different approach which makes use of phenomenological fragmentation functions (FF's). For our present exploratory study it seems sufficient to assume $\theta_h = \theta_g$. This is equivalent to $\eta_h = \eta_g = y_g$, where η_h and η_g are hadron and gluon pseudorapidity, respectively. Then

$$y_g = \text{arsinh} \left(\frac{m_{t,h}}{p_{t,h}} \sinh y_h \right) , \quad (2)$$

where the transverse mass $m_{t,h} = \sqrt{m_h^2 + p_{t,h}^2}$. In order to introduce phenomenological FF's one has to define a new kinematical variable. In accord with e^+e^- and ep collisions I define a quantity z by the equation $E_h = zE_g$. This leads to the relation

$$p_{t,g} = \frac{p_{t,h}}{z} J(m_{t,h}, y_h) , \quad (3)$$

where $J(m_{t,h}, y_h)$ is given in Ref.[11]. Now we can write the single particle distribution in terms of the gluon distribution as follows

$$\begin{aligned} \frac{d\sigma(\eta_h, p_{t,h})}{d\eta_h d^2p_{t,h}} &= \int dy_g d^2p_{t,g} \int dz D_{g \rightarrow h}(z, \mu_D^2) \\ &\delta(y_g - \eta_h) \delta^2 \left(\vec{p}_{t,h} - \frac{z \vec{p}_{t,g}}{J} \right) \cdot \frac{d\sigma(y_g, p_{t,g})}{dy_g d^2p_{t,g}} . \end{aligned} \quad (4)$$

In the present calculation I shall use only LO FF's from [12].

Let us analyze now how the results for pseudorapidity distributions depend on the choice of the UGD. In Fig.2 I compare pseudorapidity distribution of charged pions for different models of UGD's. In this calculation FF from [12] has been used.

In contrast to Ref.[3], where the whole pseudorapidity distribution, including fragmentation regions, has been well described in an approach similar to the one presented here, in the present approach pions produced from the fragmentation of gluons in the $gg \rightarrow g$ mechanism populate only midrapidity region, leaving room for other mechanisms in the fragmentation regions. These mechanisms involve quark/antiquark degrees of freedom or leading protons among others. This strongly suggests that the agreement of the result of the $gg \rightarrow g$ approach with the PHOBOS distributions [2] in Ref.[3] in the true fragmentation region is rather due to approximations made in [3] than due to correctness of the reaction mechanism. In principle, this can be verified experimentally at RHIC by measuring the π^+/π^- ratio in proton-proton scattering as a function of (pseudo)rapidity in possibly broad range. The BRAHMS experiment can do it even with the existing apparatus.

In Fig.3 I compare the theoretical transverse momentum distributions of charged pions obtained with different gluon distributions with the UA1 collaboration data [14]. The best agreement is obtained with the Karzeev-Levin gluon distribution. The distribution with the GBW model is much too steep in comparison to experimental data. This is probably due to neglecting QCD evolution in [7].

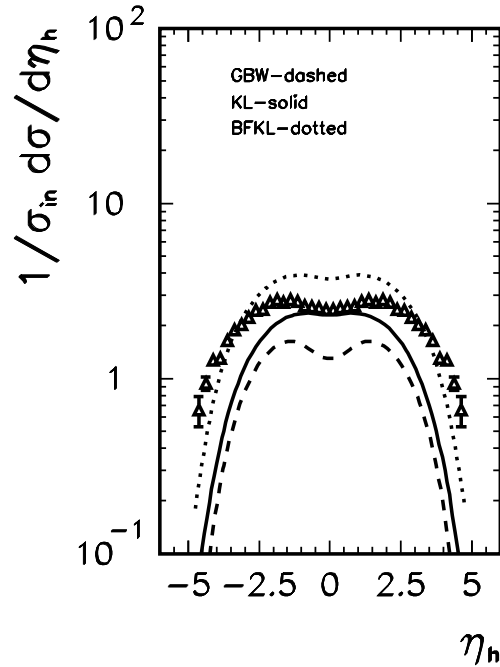


Figure 2: Charged-pion pseudorapidity distribution at $W = 200$ GeV for different models of UGD's. In this calculation $p_{t,h} > 0.2$ GeV. The experimental data of the UA5 collaboration are taken from [13].

4 Conclusions

I have calculated the inclusive distributions of gluons and associated charged π 's in the NN collisions through the $gg \rightarrow g$ mechanism in the k_t -factorization approach. The results for several UGD's proposed recently have been compared. The results, especially $p_{t,h}$ distributions, obtained with different models of UGD's differ considerably.

Contrary to a recent claim in Ref.[3], we have found that the gluonic mechanism discussed does not describe the inclusive spectra of charged particles in the fragmentation region, i.e. in the region of large (pseudo)rapidities for any UGD from the literature. Clearly the gluonic mechanism is not the only one.

Since the mechanism considered is not complete, it is not possible at present to precisely verify different models of UGD's. The existing UGD's lead to the contributions which almost exhaust the strength at midrapidities and leave room for other mechanisms in the fragmentation regions. It seems that a measurement of p_t distributions of particles at RHIC should be helpful to test better different UGD's.

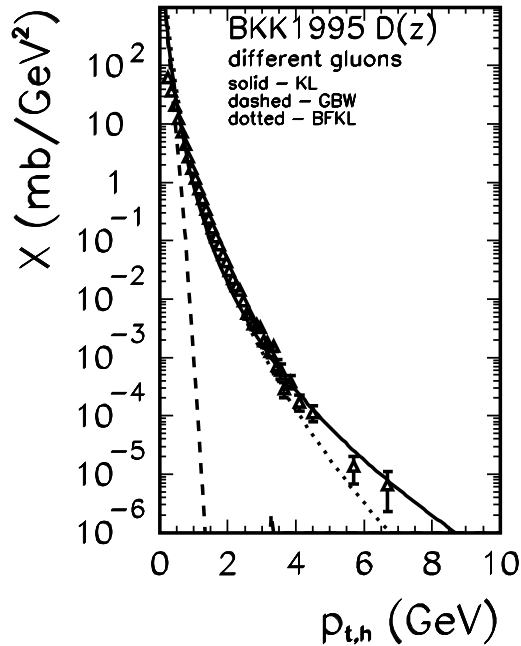


Figure 3: Transverse momentum distributions of charged pions at $W = 200$ GeV for BKK1995 FF and different UGD's. The experimental data are taken from [14].

References

- [1] Proceedings of the Quark Matter 2002 conference, July 2002, Nantes, France, to be published.
- [2] B.B. Back et al.(PHOBOS collaboration), Phys. Rev. Lett. **87** (2001) 102303-1.
- [3] D. Kharzeev and E. Levin, Phys. Lett. **B523** (2001) 79.
- [4] I.G. Bearden et al.(BRAHMS collaboration), Phys. Rev. Lett. **87** (2001) 112305.
- [5] A.J. Askew, J. Kwieciński, A.D. Martin and P.J. Sutton, Phys. Rev. **D49** (1994) 4402.
- [6] K. Golec-Biernat and M. Wüsthoff, Phys. Rev. **D59** (1999) 014017.
- [7] K. Golec-Biernat and M. Wüsthoff, Phys. Rev. **D60** (1999) 114023-1.
- [8] M.A. Kimber, A.D. Martin and M.G. Ryskin, Eur. Phys. J. **C12** 655;
M.A. Kimber, A.D. Martin and M.G. Ryskin, Phys. Rev. **D63** (2001) 114027-1.
- [9] J. Blümlein, a talk at the workshop on Deep Inelastic Scattering and QCD, hep-ph/9506403.
- [10] L.V. Gribov, E.M. Levin and M. G. Ryskin, Phys. Lett. **B100** (1981) 173.

- [11] A. Szczurek, Acta Phys. Polon. **34** (2003) 3191.
- [12] J. Binnewies, B.A. Kniehl, G. Kramer, Phys. Rev. **D52** (1995) 4947.
- [13] G.J. Alner et al. (UA5 collaboration), Z. Phys. **C33** (1986) 1.
- [14] C. Albajar et al. (UA1 collaboration), Nucl. Phys. **B335** (1990) 261.